



EXPOSURE METHOD AND APPARATUS

FIELD OF THE INVENTION AND RELATED ART

This invention relates to an exposure method  
5 and apparatus suitably usable, for example, for  
manufacture of semiconductor devices such as ICs or  
LSIs. In another aspect, the invention is concerned  
with a device manufacturing method for manufacturing  
microdevices by using such an exposure method or  
10 apparatus.

An exposure apparatus is used to expose a  
wafer having a resist applied thereto to a pattern of  
a semiconductor chip (e.g. IC or LSI) with exposure  
light. In this exposure process, a portion of the  
15 exposure light is detected by using a light dividing  
element which is disposed along the path of the  
exposure light from a light source and which is placed  
between the light source and the semiconductor chip  
pattern. On the basis of the light detection, the  
20 integrated quantity of the partial light is measured  
and the amount of exposure is controlled. Such  
exposure controlled is done on an assumption that the  
ratio of the intensity of the partial light to the  
intensity of the exposure light impinging on the wafer  
25 is constant.

However, the applicant has found that, during  
repetition of the exposure process using the exposure

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apparatus, the light absorptivity of a condenser lens which may be disposed between the light dividing element and the semiconductor chip pattern and/or the light absorptivity of a projection optical system for projecting the chip pattern onto the wafer may change, and that as a result the ratio of the intensity of the partial light mentioned above to the intensity of the exposure light impinging on the wafer may change. If it changes, then correct exposure control is not attainable.

#### SUMMARY OF THE INVENTION

It is accordingly an object of the present invention to provide an improved exposure method and/or apparatus by which the amount of exposure can be controlled precisely.

It is another object of the present invention to provide an improved device manufacturing method based on such an exposure method or apparatus.

In accordance with an aspect of the present invention, there is provided an exposure method wherein exposures are made repeatedly, said method comprising the steps of: controlling an amount of exposure on the basis of detection of an integrated light quantity of a portion of exposure light used for an exposure; and detecting, in response to completion

of each exposure or exposures of a determined number,  
a ratio in intensity of the exposure light upon a  
substrate being exposed and the portion of the  
exposure light which ratio is used for the exposure  
5 amount control.

In accordance with another aspect of the  
present invention, there is provided an exposure  
apparatus, comprising: a light dividing means disposed  
along a path of exposure light to extract a portion of  
10 the exposure light; exposure control means for  
detecting an integrated light quantity of the portion  
of the exposure light extracted by said light dividing  
means, to control the amount of exposure; and ratio  
detecting means for detecting, in response to  
15 completion of each exposure or a predetermined number  
of exposures, a ratio in intensity of the extracted  
portion and the exposure light upon a substrate, which  
ratio is used for the exposure amount control.

In accordance with a further aspect of the  
20 present invention, there is provided an exposure  
method wherein exposures are made repeatedly, said  
method comprising the steps of: controlling an amount  
of exposure on the basis of detection of an integrated  
light quantity of a portion of exposure light used for  
25 an exposure; and detecting a change in ratio of the  
intensity of the exposure light upon a substrate being  
exposed and the intensity of the portion of the

exposure light.

In accordance with a still further aspect of the present invention, there is provided an exposure apparatus, comprising: a light dividing means disposed  
5 along a path of exposure light to extract a portion of the exposure light; exposure control means for detecting an integrated light quantity of the portion of the exposure light extracted by said light dividing means, to control the amount of exposure; and  
10 detecting means for detecting a change in ratio of the intensity of the extracted portion and the intensity of the exposure light upon a substrate.

In one preferred form of an exposure method or apparatus of the present invention, a first  
15 photodetector is used to receive the portion of the light to produce a signal corresponding to the intensity of the received light. A second photodetector having a light receiving surface disposed substantially at the same level as the  
20 substrate is used to receive the exposure light to produce a signal corresponding to the intensity thereof. The ratio in intensity is determined on the basis of these signals.

In another preferred form of an exposure  
25 method or apparatus of the present invention, the intensity ratio is determined on the basis of information which concerns changes in transmissivity,

with respect to the exposure light, of an optical system for projecting the exposure light to the substrate after the portion being extracted.

5        These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view of a first embodiment of the present invention.

15        Figure 2 is a graph for explaining exposure correction made in the first embodiment.

Figure 3 is similar to Figure 2, but it explains another example of exposure correction.

Figure 4 is similar to Figure 2 or 3, but it explains a further example of exposure correction.

20        Figure 5 is a schematic view of a second embodiment of the present invention.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

25        Figure 1 schematically shows a main portion of a first embodiment of the present invention.

Denoted in the drawing at 2 is an elliptical mirror, and denoted at 1 is a light emitting tube

(light source) having a high-luminance light emitting portion 1a adapted to emit ultraviolet rays or deep ultraviolet rays. The light emitting portion 1a is disposed close to the first focal point of the

5 elliptical mirror 2. Denoted at 3 is a cold mirror having a base and a multilayered film thereon, and it is adapted to transmit almost all infrared rays therethrough but reflect almost all ultraviolet rays. Through cooperation of this cold mirror, the

10 elliptical mirror 2 serves to form an image (light source image) 1b of the light emitting portion 1a in the neighbourhood of the second focal point thereof. Denoted at 4 is a shutter which is disposed adjacent to the second focal point of the elliptical mirror 2.

15 Denoted at 5 is an optical system for imaging the light source image 1b, formed adjacent to the second focal point, upon the entrance surface 6a of an optical integrator 6. The optical integrator 6 comprises a plurality of minute lenses 6i ( $i = 1$  to  $N$ )

20 arrayed two-dimensionally with a predetermined pitch, and it serves to form a secondary light source in the neighbourhood of the light exit surface 6b thereof.

Denoted at 7 is a light collecting lens by which the light emerging from the secondary light

25 source, adjacent to the light exit surface 6b of the optical integrator 6, is collected. A portion of the collected light is reflected by a half mirror (light

dividing element) 8. The reflected light is directed to a masking blade means 10, to illuminate the opening of the masking blade means uniformly. The masking blade means 10 comprises a plurality of movable light blocking plates, and it serves to define an opening of a desired shape.

Denoted at 9 is an integrated light quantity detector. It serves to detect the light transmitted through the half mirror 8, to indirectly detect the amount of exposure of the surface of a wafer 14.

Denoted at 11 is an imaging lens for projecting an image of the opening of the masking blade means 10 upon the surface of a reticle 12 (which is the surface to be illuminated in this occasion), to thereby uniformly illuminate an appropriate region of the reticle 12.

Denoted at 13 is a projection optical system for projecting the circuit pattern of the reticle 12 upon the surface of the wafer 14, placed on a wafer chuck 15, in a reduced scale. Denoted at 16 is a wafer stage.

Denoted at 17 is an exposure amount detector having its light receiving surface disposed to be substantially coplanar (same level) with the wafer 14 surface. The detector 17 serves to detect all the light fluxes from the aperture of the masking blade 10, the size of which aperture may be set to be equal

to e.g. 10 mm square in terms of the wafer 14 surface, such that it functions to detect the actual illuminance (i.e. exposure amount) upon the wafer 14 surface.

5 Denoted at 19 is a computing means having a memory means. Predetected information about changes in transmissivity, depending on the exposure hysteresis, of the optical elements disposed along the optical path between the light dividing element 8 and  
10 the wafer 14 and predetected information about changes in transmissivity of them which may result from changes in environmental conditions, are stored in this memory means. The computing means calculates an actual exposure amount of the wafer 14 surface on the  
15 basis of a signal from the integrated exposure amount detector 9 and the information about changes in transmissivity memorized in the memory means, to control the opening/closing of the shutter 4 by which the exposure amount of the wafer 14 is controlled.

20 Also, the computing means determines the integrated exposure amount, representing the correct exposure amount of the wafer 14 surface, on the basis of the result of measurement of the quantity of illumination light as detected through the integrated light  
25 quantity detector 9 prior to the pattern transfer process and the result of measurement of the exposure amount as detected through the exposure amount



detector 17.

In this embodiment, the exposure amount of the wafer 14 is set correctly in the manner described above and, also, it is controlled precisely. Thus, the pattern of the reticle 12 can be transferred to the wafer surface accurately. Through appropriate developing process, etc., to be made thereafter, semiconductor devices are manufactured.

Now, the manner of controlling the exposure amount of the wafer 14 surface by using the computing means 19 will be explained in greater detail.

The transmissivity of each optical element disposed between the light dividing element 8 and the wafer 14 may change as a result of repetitions of exposure process (exposure hysteresis), and such change in transmissivity is predetected through experiments beforehand.

Figures 2 - 4 are graphs each for explaining changes in ratio of the illuminance (measured value)  $I_1$  upon the integrated light quantity detector 9 to the illuminance (actual illuminance)  $I_2$  upon the wafer 14 surface as detected through the exposure amount detector, during the exposure period and the non-exposure period, the ratio corresponding to the exposure correction value  $\phi (= I_1/I_2)$ . The axis of abscissa in each graph denotes time  $t$ .

In Figure 2, the ratio (hereinafter "exposure

correction value")  $\phi$  as the exposure process is going to be executed initially is taken as  $\phi = 1$ .

In this drawing, illustrated in sections A, C and E are changes in exposure correction value  $\phi$  during the exposure period, while illustrated in sections B and D are changes in exposure correction value  $\phi$  during the non-exposure period.

Now, the exposure process starts at time  $t = t_0$  (section A). The exposure correction value  $\phi_K$  during time period  $t (= t_K)$  in the section A, is expressed as follows:

$$\phi_K = f_1(t_K - t_0, e_A, e_B, \phi_0) \dots \dots \dots (1)$$

where  $e_A$  denotes the light quantity per unit time of the light impinging on the imaging lens 11,  $e_B$  denotes the light quantity per unit time of the light impinging on the projection optical system B, and  $\phi_0$  denotes the exposure correction value just before the start of the exposure operation ( $\phi_0 = 1$ , in this occasion). The light quantities  $e_A$  and  $e_B$  depend on the intensity  $I_1$  of the light reflected by the light dividing element 8, the opening size (area)  $S_m$  of the masking blade means 10 and the average transmissivity  $R_r$  of the reticle 12. Therefore, equation (1) can be rewritten as follows:

$$\phi_K = f_2(t_K - t_0, I_1, S_m, R_r, \phi_0) \dots \dots (2)$$

The opening area  $S_m$  of the masking blade means 10 and the average transmissivity  $R_r$  of the

reticle 12 are inputted into the computing means 19 in the exposure operation (or these data may be read automatically), on the basis of which the exposure correction value  $\phi$  changeable momentarily is

5 calculated and, by using the exposure correction value  $\phi$  and the light quantity (illuminance) as detected through the integrated light quantity detector, the exposure amount is controlled correctly.

Then, the exposure operation is stopped at  
10 time  $t = t_1$  and it is restarted at time  $t = t_2$ . The exposure correction value  $\phi_1$  at time  $t = t_1$  is calculated in accordance with  $\phi_1 = f_2(t_1 - t_0, I_1, S_m, R_r, \phi_0)$  while the exposure correction value  $\phi_2$  at time  $t = t_2$  is calculated in accordance with  $\phi_2 = f_3(t_2 - t_1, \phi_1)$ .  
15 After start of the exposure operation, the exposure correction value  $\phi_j$  at time  $t = t_j$  can be calculated in accordance with  $\phi_j = f_2(t_j - t_2, I_1, S_m, R_r, \phi_2)$ . In this manner, the just preceding exposure correction value and the time elapsed (exposure period  
20 time and non-exposure period time) are memorized, on the basis of which the current exposure correction value can be calculated constantly. It is to be noted that the functions  $f_2$  and  $f_3$  are determined beforehand through experiments.

25 In this embodiment, changes in exposure correction value  $\phi$  during the exposure operation are calculated successively and, for each shot of the

wafer, the exposure control is made. However, the exposure time for one shot is very short and the exposure correction value does not substantially change during such short period. Therefore,  
5 calculation of the exposure correction value  $\phi$  and exposure control based on this may be done for every plural shots or for every one wafer having plural shots.

Figure 3 corresponds to a case where each  
10 exposure correction value  $\phi$  is calculated for every plural shots and, based on this, exposure control is done. The exposure of a first shot is made during time  $t_0$  to  $t_1$ , the exposure of a second shot is made during time  $t_2$  to  $t_3$  and the exposure of a third shot  
15 is made during time  $t_4$  to  $t_5$ . Changes in exposure correction value during these time periods are depicted by broken lines.

In this example, as an inherent exposure correction value peculiar to each shot, an exposure  
20 correction value  $\phi_0$  is used for the first shot, an exposure correction value  $\phi_2$  is used for the second shot, and an exposure correction value  $\phi_4$  is used for the third shot. These exposure correction values ( $\phi_1$ ,  $\phi_2$ ,  $\phi_3$ , ....) may be calculated in the same manner as  
25 in the first embodiment.

Figure 4 corresponds to a case where, for each wafer, one exposure correction value is

calculated and, based on this, the exposure control is done. During time  $t_0$  to  $t_1$ , the exposure of a first wafer is made. From time  $t_2$ , the exposure of a second wafer starts. The exposure process of each wafer  
5 comprises exposures of a number of shots.

In this example, an inherent or predetermined exposure correction value is used in the exposure process of each wafer. In this occasion, the exposure process of one wafer comprises repetitions of exposure  
10 periods and non-exposure periods. Momentarily changeable exposure correction value may be calculated successively to determine the exposure correction value  $\phi_1$ . Alternatively, since each non-exposure period is very short, the exposures to be made to one  
15 wafer may be considered as a single exposure process and the exposure correction value  $\phi_1$  may be determined on the basis of an average received light quantity.

Where the transmissivity changes with a change in environmental condition, a sensor (not  
20 shown) may desirably be used to monitor such change in environment so that the exposure correction may be done on the basis of calculation and the result of monitoring.

Figure 5 is a schematic view of a second  
25 embodiment of the present invention.

In this embodiment, a pulse emission type light source 20 such as a KrF excimer laser, for

example, is used. The remaining structure of this embodiment is essentially the same as that of the first embodiment.

5 In this embodiment, the exposure process of one shot comprises repetitions of exposure periods and non-exposure periods. Thus, an average received light quantity is used.

10 In the above-described embodiments, the exposure correction value is calculated on the basis of exposure hysteresis. However, each exposure correction value  $\phi$  ( $= I_1/I_2$ ) may be calculated directly for every shot, for every wafer or for every wafer lot, by using the exposure amount detector 17 and the integrated light quantity detector 9.

15 Also, calibration of  $\phi$  may be done by using the detectors 17 and 19 at regular intervals, so as to correct any error between the calculated value of the exposure correction value and the actual value during the operation.

20 While the invention has been described with reference to the structures disclosed herein, it is not confined to the details set forth and this application is intended to cover such modifications or changes as may come within the purposes of the  
25 improvements or the scope of the following claims.

WHAT IS CLAIMED IS:

1. An exposure method wherein exposures are made repeatedly, said method comprising the steps of:

controlling an amount of exposure on the  
5 basis of detection of an integrated light quantity of  
a portion of exposure light used for an exposure; and  
detecting, in response to completion of each  
exposure or exposures of a determined number, a ratio  
in intensity of the exposure light upon a substrate  
10 being exposed and the portion of the exposure light  
which ratio is used for the exposure amount control.

2. A method according to Claim 1, wherein the  
substrate comprises a wafer having a number of shot  
15 areas thereon and wherein the ratio in intensity is  
detected in response to completion of the exposure of  
each shot of the wafer.

3. A method according to Claim 1, wherein the  
20 substrate comprises a wafer having a number of shot  
areas thereon and wherein the ratio in intensity is  
detected in response to completion of exposures of a  
predetermined number of shots of the wafer.

25 4. A method according to Claim 1, wherein the  
substrate comprises a wafer having a number of shot  
areas thereon and wherein the ratio in intensity is

detected in response to completion of exposures of each wafer.

5        5.    A method according to Claim 1, wherein the substrate comprises a wafer having a number of shot areas thereon and wherein the ratio in intensity is detected in response to completion of exposures of a predetermined number of wafers.

10        6.    A method according to Claim 1, wherein said detection of the integrated light quantity comprises receiving the portion of the light with a first photodetector to produce a signal corresponding to the intensity of the received portion of the light, and  
15        receiving the exposure light with a second photodetector having a light receiving surface disposed substantially at the same level as the substrate to produce a signal corresponding to the intensity of the received exposure light.

20        7.    A method according to Claim 1, wherein said detection of the integrated light quantity comprises calculating the ratio in intensity on the basis of information about changes in transmissivity, with  
25        respect to the exposure light, of an optical system for projecting to the substrate the exposure light after the portion of the light being extracted.



8. A method according to Claim 7, wherein the information about changes in transmissivity comprises a data related to changes in transmissivity resulting  
5 from hysteresis of exposure.

9. A method according to Claim 7, wherein the information about changes in transmissivity comprises a data related to changes in transmissivity resulting  
10 from hysteresis of exposure and a change in environment.

10. A device manufacturing method which comprises exposing a substrate to a device pattern of an  
15 original in accordance with an exposure method as recited in any one of Claims 1 - 9 to transfer the device pattern to the substrate.

11. An exposure apparatus, comprising:  
20 a light dividing means disposed along a path of exposure light to extract a portion of the exposure light;

exposure control means for detecting an integrated light quantity of the portion of the exposure light extracted by said light dividing means,  
25 to control the amount of exposure; and

ratio detecting means for detecting, in

response to completion of each exposure or a predetermined number of exposures, a ratio in intensity of the extracted portion and the exposure light upon a substrate, which ratio is used for the exposure amount control.

12. An apparatus according to Claim 11, wherein the substrate comprises a wafer having a number of shot areas thereon and wherein the ratio in intensity is detected in response to completion of the exposure of each shot of the wafer.

13. An apparatus according to Claim 11, wherein the substrate comprises a wafer having a number of shot areas thereon and wherein the ratio in intensity is detected in response to completion of exposures of a predetermined number of shots of the wafer.

14. An apparatus according to Claim 11, wherein the substrate comprises a wafer having a number of shot areas thereon and wherein the ratio in intensity is detected in response to completion of exposures of each wafer.

15. An apparatus according to Claim 11, wherein the substrate comprises a wafer having a number of shot areas thereon and wherein the ratio in intensity

is detected in response to completion of exposures of a predetermined number of wafers.

16. An apparatus according to Claim 11, further  
5 comprising a second photodetector having a light receiving surface disposed substantially at the same level as the substrate, for receiving the exposure light to detect the intensity of the exposure light.

10 17. An apparatus according to Claim 11, wherein said detecting means calculates the ratio in intensity on the basis of information about changes in transmissivity, with respect to the exposure light, of an optical system for projecting to the substrate the  
15 exposure light after the portion of the light being extracted.

18. An apparatus according to Claim 17, wherein the information about changes in transmissivity  
20 comprises a data related to changes in transmissivity resulting from hysteresis of exposure.

19. An apparatus according to Claim 17, wherein the information about changes in transmissivity  
25 comprises a data related to changes in transmissivity resulting from hysteresis of exposure and a change in environment.

20. An exposure method wherein exposures are made repeatedly, said method comprising the steps of:

controlling an amount of exposure on the  
5 basis of detection of an integrated light quantity of  
a portion of exposure light used for an exposure; and  
detecting a change in ratio of the intensity  
of the exposure light upon a substrate being exposed  
and the intensity of the portion of the exposure  
10 light.

21. A method according to Claim 20, wherein the  
substrate comprises a wafer having a number of shot  
areas thereon and wherein the ratio in intensity is  
15 detected in response to completion of the exposure of  
each shot of the wafer.

22. A method according to Claim 20, wherein the  
substrate comprises a wafer having a number of shot  
20 areas thereon and wherein the ratio in intensity is  
detected in response to completion of exposures of a  
predetermined number of shots of the wafer.

23. A method according to Claim 20, wherein the  
25 substrate comprises a wafer having a number of shot  
areas thereon and wherein the ratio in intensity is  
detected in response to completion of exposures of

each wafer.

24. A method according to Claim 20, wherein the substrate comprises a wafer having a number of shot  
5 areas thereon and wherein the ratio in intensity is detected in response to completion of exposures of a predetermined number of wafers.

25. A method according to Claim 20, wherein said  
10 detection of the integrated light quantity comprises receiving the portion of the light with a first photodetector to produce a signal corresponding to the intensity of the received portion of the light, and receiving the exposure light with a second  
15 photodetector having a light receiving surface disposed substantially at the same level as the substrate to produce a signal corresponding to the intensity of the received exposure light.

20 26. A method according to Claim 20, wherein said detection of the integrated light quantity comprises calculating the ratio in intensity on the basis of information about changes in transmissivity, with respect to the exposure light, of an optical system  
25 for projecting to the substrate the exposure light after the portion of the light being extracted.

27. A method according to Claim 26, wherein the information about changes in transmissivity comprises a data related to changes in transmissivity resulting from hysteresis of exposure.

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28. A method according to Claim 26, wherein the information about changes in transmissivity comprises a data related to changes in transmissivity resulting from hysteresis of exposure and a change in

10 environment.

29. A device manufacturing method which comprises exposing a substrate to a device pattern of an original in accordance with an exposure method as  
15 recited in any one of Claims 20 - 28 to transfer the device pattern to the substrate.

30. An exposure apparatus, comprising:

20 a light dividing means disposed along a path of exposure light to extract a portion of the exposure light;

exposure control means for detecting an integrated light quantity of the portion of the exposure light extracted by said light dividing means,  
25 to control the amount of exposure; and

detecting means for detecting a change in ratio of the intensity of the extracted portion and

the intensity of the exposure light upon a substrate.

31. An apparatus according to Claim 30, wherein  
the substrate comprises a wafer having a number of  
5 shot areas thereon and wherein the ratio in intensity  
is detected in response to completion of the exposure  
of each shot of the wafer.

32. An apparatus according to Claim 30, wherein  
10 the substrate comprises a wafer having a number of  
shot areas thereon and wherein the ratio in intensity  
is detected in response to completion of exposures of  
a predetermined number of shots of the wafer.

15 33. An apparatus according to Claim 30, wherein  
the substrate comprises a wafer having a number of  
shot areas thereon and wherein the ratio in intensity  
is detected in response to completion of exposures of  
each wafer.

20 34. An apparatus according to Claim 30, wherein  
the substrate comprises a wafer having a number of  
shot areas thereon and wherein the ratio in intensity  
is detected in response to completion of exposures of  
25 a predetermined number of wafers.

35. An apparatus according to Claim 30, further

comprising a second photodetector having a light receiving surface disposed substantially at the same level as the substrate, for receiving the exposure light to detect the intensity of the exposure light.

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36. An apparatus according to Claim 30, wherein said detecting means calculates the ratio in intensity on the basis of information about changes in transmissivity, with respect to the exposure light, of an optical system for projecting to the substrate the exposure light after the portion of the light being extracted.

37. An apparatus according to Claim 36, wherein the information about changes in transmissivity comprises a data related to changes in transmissivity resulting from hysteresis of exposure.

38. An apparatus according to Claim 36, wherein the information about changes in transmissivity comprises a data related to changes in transmissivity resulting from hysteresis of exposure and a change in environment.

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